Gröna Tåget – a high-speed train for the Nordic market

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High-speed on the conventional network: Tilting trains
Sweden

First report on tilting trains in 1969.

X 2000 services begun in 1990 (Stockholm-Gothenburg), and was extended to all main lines during the 1990’s.

Successful in rail/air competition up to 400 km, and also Stockholm-Gothenb.(455 km)

Upgrading of the conventional network for up to 200 km/h operation.
New high-speed trains needed

- Travel demand increases
- Short travelling times are profitable (for society as well as for operators and passengers)
- Lower fares through better economy of service
- Existing trains grow older

New links and rebuilt sections since mid-1990’s
dimensioned for 250 km/h with tilting trains
(mixed freight and passenger)
The Gröna Tåget research programme

- Trafikverket, KTH, research institutes, Bombardier, SJ AB, consultants
- 2005-2011
Gröna Tåget
Grønne Toget/The Green Train

• "Gröna Tåget should serve as a bank of ideas, proposals and technical solutions for operators, infrastructure managers and industry”

• Flexible train length: Capacity according to need
• Many seats in a given train length
• Reliability and accessibility even in the Nordic climate
• Low costs give profitability in a market exposed to competition
• Track-friendliness, which means less wear to track and wheels and enables high speeds on non-perfect track
• Even lower energy consumption and less noise than trains of today
Carbody tilt
To increase speed in curves
Boogie technology
Track-friendly soft boogie
The Gröna Tåget cost model

- Train data
- Type of service
- Load factor

- Capital costs
- Onboard personnel costs
  - Terminal costs
  - Energy costs
  - Maintenance costs
  - Infrastructure user fees
  - Sales costs
  - Administration and planning

Calculation of general operational costs
- Cost per train-km
- Cost per passenger-km
- Cost per seat-km

Calculation of operational costs per case
Most important factors for low costs in train operations

- High commercial speed*
- Efficient space utilisation
- High load factor

* More important: Increases demand as well
Total operational cost as a function of commercial speed

![Graph showing the relationship between total operational cost (in SEK/seat-km) and commercial speed (km/h). The graph indicates a downward trend as speed increases.]
Total operational cost as a function of space utilisation
Total operational cost as a function of load factor

![Graph showing the total operational cost as a function of load factor. The cost decreases as the load factor increases.](image-url)
Gröna Tåget high-speed concept

- Carbody tilt (optional)
- High top speed of 250 km/h on conventional lines, a 320 km/h version for new lines possible
- Wide-body
- Shorter, flexible trainsets
- Reliable in Nordic winter
- Lower total costs
- Lower energy consumption (economy and energy efficient)
Carbody width

ICE3
Continental profile

Gröna Tåget
Wide body
*Norway, Sweden, Copenhagen*
Comparison of train sets

**Space utilisation**
- Wide-body trains have 25-30% more seats in every car
- Space efficient seats and train layout
- An EMU is lacking a locomotive/power unit (cf. the X 2000)

Illustration by Oskar Fröidh, 2010
Effects of Gröna Tåget

Higher top speed (250 km/h up)
Tilting capability
Wide body (2+3 seating)
Shorter trainsets, flexible train length

Market effects
• Increased travel demand
• Improved economy of operation
• Increased accessibility, cost-benefit ratio improves
• Less air and car travel – sustainable environment
Suggested strategy

The Oslo–Stockholm corridor

Map: Oskar Fröidh, 2010

2010-12-16 Gröna Tåget – a high-speed train. Oskar Fröidh, KTH
Total operating costs
The Gröna Tåget cost model
Applied on Oslo–Stockholm corridor
Lower ticket price – more journeys
The Oslo–Stockholm corridor

- Total operating cost for 1 single journey in 2010’s prices
- Operating cost *not* the same as ticket price (which includes yield management and profit), but an indication

**Existing line (570 km, 4h50)**

<table>
<thead>
<tr>
<th>Train type</th>
<th>Operating cost</th>
<th>Travel demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSB BM73</td>
<td>NOK 428</td>
<td>ref.</td>
</tr>
<tr>
<td>SJ X 2000</td>
<td>NOK 411</td>
<td>+3%</td>
</tr>
<tr>
<td>Gröna Tåget (GTW-4)</td>
<td>NOK 347</td>
<td>+15%</td>
</tr>
</tbody>
</table>

**High-speed line (491 km, 2h30)**

<table>
<thead>
<tr>
<th>Train type</th>
<th>Operating cost</th>
<th>Travel demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB ICE3</td>
<td>NOK 312</td>
<td>ref.</td>
</tr>
<tr>
<td>Gröna Tåget (GTW-6)</td>
<td>NOK 256</td>
<td>+14%</td>
</tr>
</tbody>
</table>

1) Load factor 60%
2) At a fare elasticity of -0.8
Total operating costs
Gröna Tåget cost model
Applied on Oslo–Stockholm corridor

High-speed has 20% lower operating costs than services on a conventional line. Effect of **shorter distance and time**

Efficient **space utilisation** (Wide-body) has 15% lower operating costs than continental carboby
Gröna Tåget in Scandinavia

• Higher speeds (250 km/h or more) of interest in all countries (DK, FI, NO, SE)
• Conventional network supplemented by new high-speed links
• Wide-bodied trains possible (according to European norms, but critical in DK)
• Many prerequisites in common (climate, market, economy, social order)
• Larger market for improved design and lower price of trains
Energy consumption
All modes, Norway

Figur 3: Energiforbruk per personkm fordelt på transportmidler

From www.jernbaneverket.no
Energy consumption
Stockholm–Gothenburg (455 km)

**Existing main line**

<table>
<thead>
<tr>
<th>Train Type</th>
<th>Speed</th>
<th>Time (hrs)</th>
<th>Load Factor</th>
<th>Energy Consumption (Wh/pass.-km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old loco-hauled train</td>
<td>160 km/h</td>
<td>4</td>
<td>Lf*44%</td>
<td>108 ¹</td>
</tr>
<tr>
<td>X 2000</td>
<td>200 km/h</td>
<td>2h45</td>
<td>Lf*55%</td>
<td>77</td>
</tr>
<tr>
<td>Gröna Tåget</td>
<td>250 km/h</td>
<td>2h30</td>
<td>Lf*60%</td>
<td>52</td>
</tr>
</tbody>
</table>

**New high-speed line (Götaland line)**

<table>
<thead>
<tr>
<th>Train Type</th>
<th>Speed</th>
<th>Time (hrs)</th>
<th>Load Factor</th>
<th>Energy Consumption (Wh/pass.-km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gröna Tåget</td>
<td>320 km/h</td>
<td>2</td>
<td>Lf*60%</td>
<td>69</td>
</tr>
</tbody>
</table>

**Reference values**

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Energy Consumption (Wh/pass.-km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European high-speed average (2009; Lf*65%)</td>
<td>61 ²</td>
</tr>
<tr>
<td>Airplane (Boeing 737-800; Lf*65%)</td>
<td>510 ³</td>
</tr>
</tbody>
</table>

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1) Equivalent to NSB average today
2) Longer trains than on Stockholm-Gothenburg
3) Energy content in fuel

* Load factor/Cabin factor; Share of occupied seats
Energy supply and the environment

- Railways use 1-2% of electricity (Sweden)
- Environmental load, incl. emissions of $CO_2$, dependent on energy source for electricity generation
- Electricity mix on the common Nordic market gives relatively low $CO_2$ emissions due to high proportion of hydroelectric and nuclear* power
- For increased steady use, biofuel, wind, hydroelectric, nuclear* and natural gas are more or less economic and likely power sources
- Limited grid transfer capacity and high costs make for example German coal power only a marginal option

* Finland, Sweden
How can Gröna Tåget contribute to the Norwegian High-speed rail assessment?

- Economic and environmental friendly concept solution for existing lines as well as new high-speed lines
- Increased travel demand due to shorter travelling times and lower operating costs (lower ticket prices)
- A technical solution (tilting carbodies, track-friendly boogies, winter ability) that suits Nordic operators
- A flexible concept on a common technical platform assures lower prices for standardised rolling stock
Illustrationer från Konstfack, Stockholm University College of Arts Crafts and Design

www.infra.kth.se/jvg
www.gronataget.se